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# Biofiltration of Acetic Acid Vapours Using Filtering Bed Compost from Poultry Manure - Pruning Residues - Rice Husks

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Volatile organic compounds (VOCs) are generated by important economic activities such as: Chemical production plants, industrial areas, agricultural and livestock farms and waste treatment plants. These VOCs could generate annoyance and repercussions on health of the employees and the surrounding communities. Biofiltration is one of the most efficient biological technologies to eliminate these contaminants on streams with medium concentrations and high flows. Moreover, it has several advantages related to low costs of implementation and maintenance. In this work, packing materials were obtained through a composting process carried out under controlled conditions. Poultry manure (PM) as main substrate and pruning residues (PR) or rice husks (RH) as bulking materials were used during composting. Two isolated acrylic barrels (210 L) with automatized aeration were used as composters. These systems were fed with PM:PR and PM:RH in a volume ratio of 1:1 to obtain two different composts used as packing materials. A biofiltration battery was used to evaluate acetic acid removal efficiency from an air stream through the composting beds. The material moisture was fixed in 50% w.w. and the system assessment was carried out using an empty bed retention time of 66 s. The biofiltration system was exposed to concentrations in the range of 7,240 to 14,480 ppm. The removal efficiency, of both biofilters, during the experiment was in the range of 77.1 to 99.9 %. The low pollutant removal was associated with a high initial VOCs concentration in the gas stream. Nevertheless, the pruning residues bed showed a better operative performance to the transient conditions evaluated.

## 1. Introduction

At the global level, there has been a concern related to the VOC's by the industries due to the health problems that they entail (Ruiz-Ojeda et al., 2016). Within these, acetic acid affects the respiratory system generating dyspnea and pulmonary edema among others. According to this, regulations have been developed leading to implement technologies or make processes changes to carry out emission control. However, this change generates costs and sometimes the alternatives implemented have not been enough. In industrial sectors, such as oil and agroindustrial, and wastewater treatment plants several types of VOC's and odors are emitted to the environment. In Colombia, chicken meat demand has grown continuously until reaching 30.4 kg of chicken per person in 2,015. This behavior has led to an emissions intensification where some of the main compounds emitted are: acetic acid, 2,3-butanedione, methanol, acetone and ethanol. In poultry industry, acetic acid reaches a concentration of 1,922.3 $\mu g m^{-3}$ (Trabue et al., 2010). Currently, there are technologies for VOCs treatment such as adsorption, cryogenic condensation, absorption, thermal and catalytic oxidation and membrane separation, reverse osmosis, nanofiltration, activate charcoal filters (Almarcha et al., 2014). Nevertheless, all the above-mentioned procedures have high investment cost, specific maintenance and the possibility of secondary pollutants generation. An inexpensive, efficient and suitable alternative to remove volatile organic compounds is biofiltration. This biological process degrades pollutants from a gaseous stream through adsorption, absorption and degradation. The most used materials are composting from wood,

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manure, peat and soil. In this treatment, conditions such as moisture, temperature, pH, pollutant concentration and input rate must be taken into account. This project was divided into stages: collecting information about VOCs generated in poultry activity, characterization of composting raw materials, composting process, pollutant selection, design, construction and biofiltration system start-up and removal efficiency evaluation. Two composts generated from poultry manure and lignocellulosic material, were used as biofiltration bed.

## 2. Materials and Methods

### 2.1 Composters

The main material used for the composting was poultry manure, which was supplied by the company Agroinca S.A.S. located in Nemocón (Colombia). The pruning was collected during the parks in the northern part of Bogota. It was reduced to a particle size of less than 25 mm. Rice husks were obtained from a crop located in Huila. Substrates selection considers factors such as C/N ratio and high biodegradability (Table 1). These materials were reported as bulking agent with high VOC's removal efficiency in biofiltration systems (Cabeza et al., 2013). Two different mixtures with a ratio of 1:1 (v/v) were used for each compost, one composed of poultry manure and pruning residues and a second one, a mixture of poultry manure and rice husks.

*Table 1: Characterization of substrates for composting*

| Characteristics | Units | PR (Pruning) | RH (Rice husks) |
|---|---|---|---|
| pH | - | 8.32 | 8.55 |
| Organic matter | $gkg^{-1}$ | 5.9 | 5.9 |
| Volatile solids[1] | $mgkg^{-1}$ | 851.3±26 | 775.5±8.2 |
| Porosity | %(v/v) | 75 (David *et al.*, 2008) | 64.75 (Molina-Salas, 2010) |
| C/N | - | 80-150:1 (Rojas and Zeledón, 2007) | 95:1 (Rojas and Zeledón, 2007) |
| BC[2] | - | 0.1192 | 0.0040 |
| Moisture | % | 50 | 50 |
| PS[3] >25 mm | % | 50 | - |
| PS[3] 10-5 mm | % | - | 50 |

[1]Average ± standard deviation on three samples for volatile solids; [2]BC: Biodegradability Coefficient; [3]PS: Particle size

#### 2.1.1 Composting system

Acrylic cylinders of 210 L and a compressor were used for the construction of the composters. Each cylinder had a working volume of 60 L of CM:PR or CM:RH with a moisture of 50% in a ratio 1:1 (v/v). All the substrates used were previously sieved to remove fine material and to avoid blockage in the air composter inputs. The air stream was supplied from the bottom. Additionally, each composter was covered with polystyrene thermal fiber isolation to prevent heat losses. Other factors considered throughout the process were moisture, volatile solids, pH and biodegradability coefficient (BC). The composting process was carried out during five (5) months, in which the factors mentioned above were monitored to ensure stable compost.

### 2.1 Biofiltration unit

The biofiltration system consists of two PVC cylinders with a diameter of 10.16 cm and 1 m in height. Biofilters were filled with 0.01 $m^3$ of mature beds (2) obtained from composting phase (Figure 1). Retention time was set at 66 s taking into account that the optimal range is between 30 s and 1 min. The inlet gas stream was supplied from the bottom of the column (ascending flow). Oil-free compressed air was humidified to 90–100% by sparging. Filter media evaluation was performed through exposure to different concentrations of acetic acid vapours (industrial grade): Days 1-11 started with acetic acid concentration of 7.240 ppm; days 12-15 acetic acid concentration was increased to 10,860 ppm; days 16-25 an acetic acid concentration of 14,480 ppm.

#### 2.2.1 Analytical methods

Filters bed moisture was determined through the norm CEN-EN 13040 standard: weekly for composting and daily for biofiltration. It was evaluated to keep moisture adjusted to 50% w.b. (Cabeza et al., 2013). Volatile solids, total solids and fixed solids were measured according to the Standard Methods (APHA, 2005). Biodegradability coefficient was calculated using the Equation 1 (Haug, 1993) to evaluate the degradation behavior of the bed material in the presence of a microbial population.

$$\mathbf{Km} = \frac{(\mathrm{OM}_1\% - \mathrm{OM}_2\%)\,100}{\mathrm{OM}_1\%(100 - \mathrm{OM}_2\%)} \quad (1)$$

Where Km is the coefficient of biodegradability, $OM_1\%$ is the total initial content of organic matter and $OM_2\%$ is the total content of total organic matter, % of total solids.

2.2.2 . COV´s measurement method

A gas detector (RKI GX-6000 industries, model bul-6000, JAPAN, VOC’s portable ana-Lyser) equipped with a 10.6 eV lamp for photoionization were used to measure the VOC’s concentration. Prior to the assay, an evaluation looking for VOC’s traces in the beds was performed. The air used to simulate the contaminated stream was previously humidified in ranges over 90% through a sparging device. VOC’s measurement was carried out six times per day during five weeks. Regardless of what gas the PID sensor is calibrated to (isobutylene by default), the PID sensor will still detect and respond to a variety of VOCs. A conversion factor (multiplying display reading by 36.2) for acetic acid and supplied by the manufacturer was used.

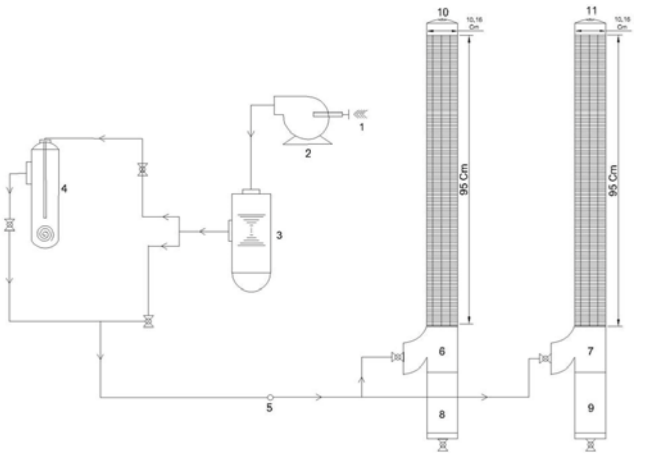


*Figure 1: Schematic of the biofiltration system. (1) air inlet; (2) compressor; (3) humidifier; (4) pollution device; (5) biofilter gas inlet/sampling port; (6 and 7) biofilters; (8 and 9) water drainage; (10 and 11) biofilter gas outlet/sampling port.*

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## 3. Analysis and Results

**3.1 Composting parameters**

3.1.1 Temperature analysis

The temperature has a large importance since the microorganisms that perform the degradation processes are developed in temperatures between 15°C and 40°C. The temperature behavior showed an initial increase due to a high availability of organic matter and nutrients, which is fundamental to produce the microbial activity (Figure 2). After the second week, there is a decrease in temperature caused by the consumption of the available organic matter by the microorganisms, but at no time lowering from 19°C remaining in the reported range (15-19°C). The relationship between temperature and microbial activity was direct in both composting process. In addition, higher temperatures were not reached because the slow degradation related to the lignocellulosic material in each mixture. There is a drop between day 10 and 15, which was related to a decrease in moisture (operative failure), which reduced microbial activity. As a result, the pruning bed had a high degradation of organic matter with a maximum temperature of 31ºC against 29ºC to the husk bed.

3.1.2 Moisture analysis

Moisture was control in a range between 40-50% to have a positive influence on the microbial population. However, points outside the optimum range for the two composters were registred. If the moisture is below 45%, the microorganisms in the compost will not have enough water and their activity will be slower. Meanwhile, an increase could reduce the porosity of the material avoiding the uniform circulation of air. In both processes, the moisture content has a big influence in the low rate of biodegradability (Figures 3 and 5).

3.1.3 pH analysis

In the first days, Figure 4, pH behavior indicates an alkaline condition for both samples; this was due to the pH of poultry manure. The change between both composters was influenced by the pH of each substrates; husk and pruning. A gradual pH decrease due to the microbial metabolism was reached from day 6 to 12, where organic acids production was given as a transformation of carbonate complexes and the incomplete oxidation of organic matter (Liu et al., 2011). During days 13 to 20, there was a pH increase as a consequence of ammonia formation associated with protein degradation and organic acids decomposition which coinciding with microbial activity at thermophilic phase. Finally, a decrease from day 20 to 30 tending to neutrality and indicating the final phase of the process or compost maturation (Altieri et al., 2011).

3.1.4 Biodegradability coefficient analysis

Biodegradability coefficient showed a high rate during the first days that could be related to the high temperature achieved in the media Figure 5. After that, decrease in temperature and moisture could affect the Km rate reducing microorganism activity (Figure 2, 3 and 5). However, biodegradability coefficient showed a direct relationship with time reaching a maximum value after 20 days. By comparing the two mixtures types, a lower biodegradability coefficient was obtained to the rice husks compost compared to pruning compost. It was due to the fact that the rice husks have a low biodegradability lignin content (Altieri et al., 2011), while pruning, being a cellulose compound, its biodegradability can reach up to 70%. Regarding the relation of Km with respect to moisture, pruning compost was favored by a higher water content (44%) compared to that of husk (40%), this is evidenced by comparing the behavior of the Km for both compost, where we can see that higher water content generates greater biodegradation of organic matter

### 3.2 Biofilter data analysis

In Figure 6, the efficiency reached 100% in the first days for the RH biofilter during the acetic acid concentration of 7,420 ppm. This efficiency was related to the hydrophilic characteristic of the pollutant, which improve adsorption and desorption with the biofilter bed. A concentration increases until 10,860 ppm was evaluated where the acetic acid removal also reached 100%. As soon as, the concentration of 14,480 ppm was applied, there was a decrease in the removal percentage across the time in relation to the other two conditions. On the first day, that this concentration was applied, an efficiency of 100% was reached and as the days go by, there was a constant reduction in the removal efficiency until 70.9%. This was argued for two reasons: 1. the medium saturation due to a high concentration combined with the accumulated time of the samples for the previous conditions; 2. a decrease of the organic matter and the nutrients, since the microorganisms use organic matter of the bed during their degradation process. This degradation at long periods of time can decrease the removal efficiency due to anaerobic zones, which are are produced by bed channeling (preferential paths) avoiding uniform oxygen distribution.

At the end of the measurements for 14,480 ppm (days 23-25), there was an increase of the pollutant removal efficiency, which was probably due to the acclimatization of the system to a new concentration as can be observed in Figure 7. It could indicate that microorganisms require an additional time to restart degradation of the compound, to get used to the new operating conditions of the system (Cabeza et al, 2013). This evaluation was done to analyze the transient conditions of operation of the biofilter and to analyze the adaptive capacity by varying the VOC concentrations present in the stream. High stability and efficient response to the concentration changes were identified. The biofilters moisture, as shown in Figure 6, is an important parameter due to its influence with respect to the microbial activity. Accordingly, a tendency towards ranges of 40% - 50% is observed to have a control of the filter beds and thus maintain levels that support the metabolic activity of the microorganisms in the biofilters (Cheng et al, 2016).

For the PR biofilter (Figure 8 and 9), a similar behavior was observed corresponding to the concentration of 7,240 ppm related to the RH biofilter. There is a small drop in the removal percentage caused by the acclimatization of the microorganisms to the pollutant. Then, for the second concentration, corresponding to 10,860 ppm, a removal of 100% was achieved on days 11-14. For the concentration of 14,480 ppm, there was a decrease in the removal that can be argued for two reasons: the first one, is the low availability of organic matter for the microorganisms in the medium due to their consumption during the first weeks; the second one, is a medium saturation caused by the acetic acid accumulation during tests of previous concentrations.

The results obtained in the tests showed removal levels above 70% for the RH biofilter and high efficiency above 90% was obtained in the PR biofilter. This was because in the PR biofilter during the composting process, the biodegradability coefficient was elevated, which makes the degradation processes by the microorganisms were improved in the pruning biofilter (Cabeza et al., 2013). According to this, it can be affirmed that for this biofilter in terms of removal it is up to and even with better results of other materials used in the biofiltration of gases, such as raschig rings or polyurethane sponge.

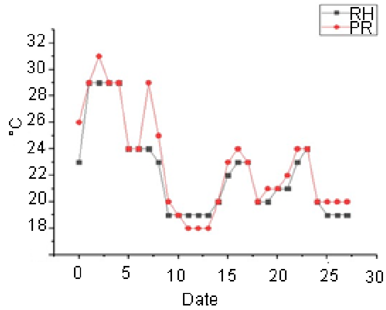


*Figure 2: Temperature as a function of time (compost process).*

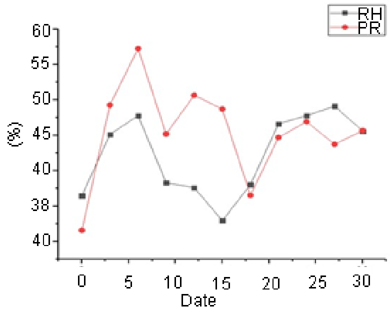


*Figure 3: Moisture as a function of time (compost process).*

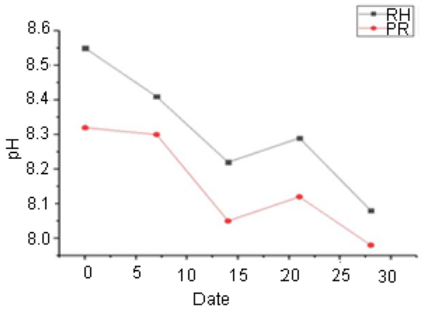


*Figure 4: pH as a function of time (compost process).*

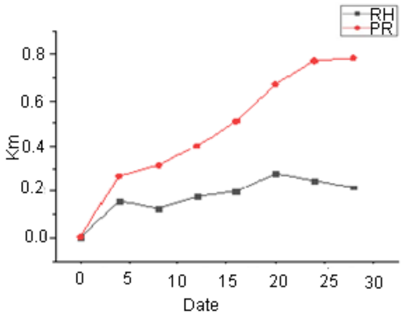


*Figure 5: BC as a function of time (compost process).*

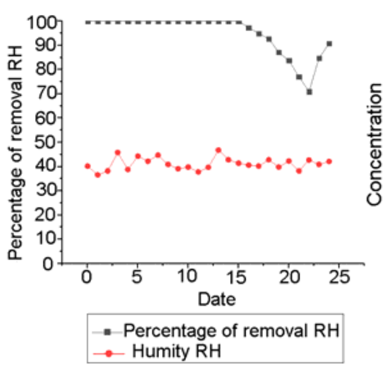


*Figure 6. Pollutant removal percentage and moisture of the medium in RH biofilter.*

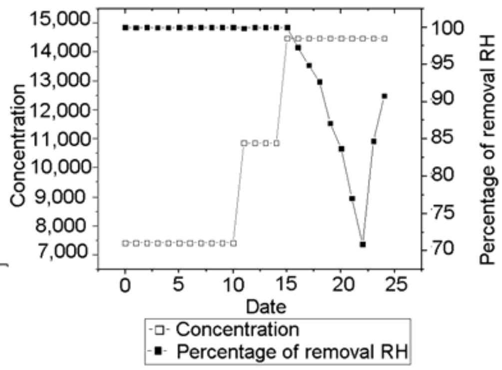


*Figure 7. Removal percentage and concentration of pollutant in RH biofilter.*

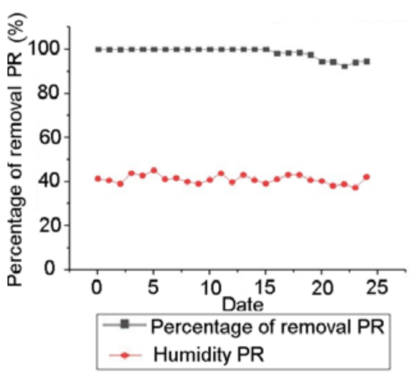


*Figure 8. Pollutant removal percentage and moisture of the medium in PR biofilter.*

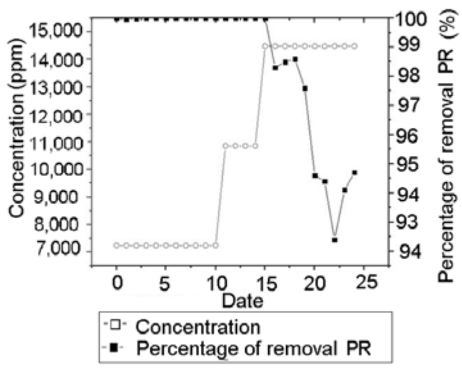


*Figure 9. Removal percentage and concentration of pollutant in PR biofilter.*

In the case of the PR biofilter, it is supposed that the yields obtained in this system are comparable with biofilters that also use other types of composting material as a filter bed, such as peat. But, it is also contemplated that it even obtains better yields than those made from sludge sewage treatment plant (Sánchez-Rodríguez et al, 2015).

## 4. Conclusions

The materials used in the first phase (PR, RH) were suitable for composting due to similar behaviors were observed in variables as temperature or biodegradability coefficient. In the acetic acid removal through biofiltration systems (PR, RH) there was not an acclimatization period. In contrast, the first week, high pollutant elimination efficiency was obtained which was related to two biofiltration factors: adsorption and absorption. The first one, because the contaminant is a polar compound that is characterized by being hydrophilic, which accelerates pollutant adhesion to the wet filter bed. The second one, the absorption depends on the biodegradability coefficient, which was high for the PR mixture. It explains the better yield for the biofilter with the pruning mixture than the yield achieved to the rice husks. The results showed that the PR medium had a high effectiveness for the removal of acetic acid concentrations. The pollutants degradation by the microbial population is almost complete which reduces the blockages events. However, if it was managing to present it is important to stop to traverse a clean draught, to degrade the pollutant present in the bed that could be generating the saturation and hereby to empty the filtering bed. The biofilter system could has a long lifetime due to the three processes involved are absortion, adsortion and biodegradation which guarantee not intermediate compounds in this kind of filters. Nevertheless, a deep gases analysis should be done to confirm completely this fact.

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